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How significant is vertical ground motion from low magnitude earthquakes?

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Up to now, almost all of the ground motion modeling and hazard assessment for seismicity in the Netherlands focuses on horizontal motion. As a rule of thumb, the strength of vertical ground motions is taken as 2/3 of that of horizontal ground motions. In reality of course, amplifications and V/H ratios are site-dependent and thus vary regionally. Recent studies have indeed shown that vertical ground motion is not always simply 2/3 of the horizontal motion. However, these studies are performed in areas with high magnitude ($M_w > 5.0$) earthquakes and the question is whether vertical motion is relevant to be included in seismic hazard assessment for low magnitude earthquakes (to date, max $M_w = 3.6$ in Groningen).

In the Netherlands, the top part of the soils is practically always unconsolidated, so the elastic waves generated by deeper (~3000m) seated earthquakes will be subject to transformation when arriving in these layers. Recordings over a range of depth levels in the Groningen borehole network show the largest amplification to occur in the upper 50 meters of the sedimentary cover. We not only observe a strong amplification from shear waves on the horizontal components, but also from longitudinal waves on the vertical component. A better understanding of vertical motion of low magnitude earthquakes aims to support the design of re-enforcement measures for buildings in areas affected by low magnitude seismicity. Furthermore, interference between the longitudinal -and shear waves might contribute to damage on structures.

This study presents observations of longitudinal wave amplification in the frequency band 1-10 Hz, corresponding to resonance periods of Dutch buildings. From 19 seismic events, with a minimum of magnitude two, we retrieved transfer functions (TFs) from the vertical component, showing a strong site response at certain locations. In addition, we calculate event V/H ratios and VH factors from the surface seismometer. These results are compared with the TFs and show a similar pattern in terms of site response. Furthermore, the sites with highest vertical amplification correspond to very low (800-900 m/s) P-wave velocities. Our study shows that vertical amplification is very site dependent. However, the question whether the vertical motion is significant enough to form a real hazard can only be answered through cooperation between seismologist and structural engineer.

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